**Public Comment on the levee fragility section of the "Initial Technical Framework" for the Delta Risk Management Strategy.**

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The Delta Risk Management Strategy is an ambitious undertaking being produced on a short timeline, and DRMS engineers are doing the best they can to analyze levee fragility using the available data. However, the results of this study are bound to be inconclusive because our current state of knowledge is inadequate to accurately characterize the response of levees under the various loading conditions being considered. The DRMS study will be a first-generation effort that will identify gaps in our knowledge that are most important for future generations of risk assessment. Subsequent work should focus on knowledge generation and data gathering to improve the reliability of the DRMS risk assessment. The response of levees to seismic loading will certainly be identified as an area requiring further study.

The most glaring deficiency in our ability to evaluate the seismic performance of levees is that we do not have a clear understanding of which of several possible deformation mechanisms is most likely critical for levee/foundation systems. Fig. 1 shows three example failure mechanisms that could result in a levee breach. Levees may slump and spread due to deviatoric shearing of the levee material and underlying peaty organic foundation soils, and due to volumetric strain of the foundation materials as pore water is expelled after shaking (Fig. 1a). Levees may slide horizontally if the foundation soils lose significant strength (Fig. 1b), as exhibited by levees at the 17th Street Canal in New Orleans due to Hurricane Katrina. Levees could also deform due to a distributed bearing failure in the soft peaty organic soils beneath the levees (Fig. 1c). Shaking might also cause cracks in a levee that ultimately result in a breach due to piping and/or erosion. Page 6 of the DRMS Initial Technical Framework specifies a Newmark sliding block approach for the analysis of levee performance. The degree to which this simplified procedure (which assumes a rigid sliding mass) can capture the mechanisms depicted in Figure 1 is unclear; it almost certainly cannot capture the phenomena represented in Figure 1a nor the cracking/erosion process described above. Relatively sophisticated dynamic finite element analyses hold the potential to more accurately capture the possible failure modes depicted in Figure 1, but at present the material behavior characteristics required to exercise such models is unavailable.

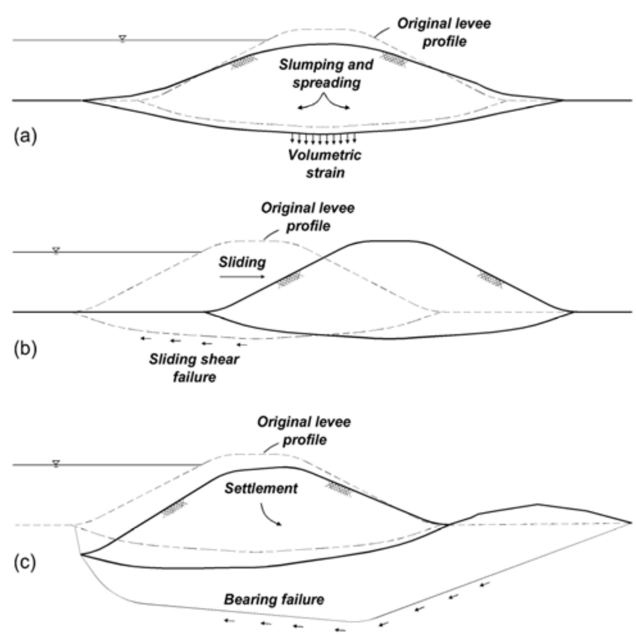


**Figure 1: Possible mechanisms of levee failure due to earthquake shaking.**

The aforementioned problems can only be adequately addressed through a carefully planned and executed program of full-scale field testing. Such testing would subject levee systems to the extreme loading that is expected from future earthquakes, causing the levees to deform in a natural way. This would provide the necessary information on critical failure mechanisms, while also providing detailed information on soil behavior to facilitate numerical modeling work.

The University of California, Los Angeles hosts a site for the George E. Brown Network for Earthquake Engineering Simulation or NEES (http://www.nees.ucla.edu). Funding of management, operations and maintenance of the NEES program by the National Science Foundation provides a mechanism for leveraging federal funds to significantly reduce the cost of research projects that utilize the NEES equipment. The nees@UCLA site specializes in field testing equipment, including mobile shakers, sensors, and a cone penetrometer rig. The mobile shakers could be mounted on the crest of an embankment in the Delta for the purpose of evaluating levee response under various shaking amplitudes and frequencies (Figs. 2-3). Sensors would be used to record the response of the embankment and foundation soils. The cone penetrometer rig would be used to characterize the site conditions, including profiles of small-strain shear wave velocity along the embankment cross section. Abandoned embankments or levees would be ideal test sites.

Testing would begin with small-amplitude shaking to identify dynamic interaction between the embankment and underlying comparably soft peat deposits. This will provide guidance on how free-field motions (which can be evaluated using currently available models/data) can be related to the motions beneath levees. Shaking amplitude would gradually be increased to measure the embankment response at various load levels, and would culminate with failure of the embankment. Results from the test(s) would be used to (1) help identify shaking demands beneath the levees, (2) identify likely levee failure mechanisms, and (3) evaluate material response characteristics (especially for the peaty foundation soils) through data from dense sensor arrays deployed in the embankment and foundation. These results would guide the development of next-generation simplified and relatively sophisticated engineering models for characterizing levee response to earthquake shaking.

**Figure 2: Eccentric mass shaker owned by nees@UCLA.**

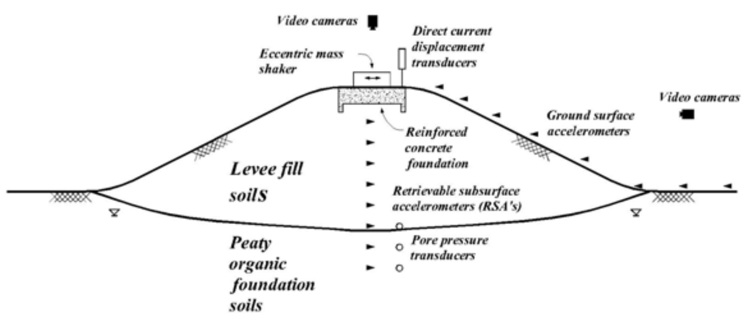


**Figure 3: Schematic experimental layout for destructive seismic field testing of a Delta embankment.**